Skeleton Migration, A Seismic Interpretation Tool

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Summary

We present a simple migration algorithm that can be applied to skeletonized (or hand-digitized) shallow as well as deep-crustal reflection seismic profiles. Our method is similar to line-drawing migration algorithms, but also accounts for the out-of-plane component of scattering for both specular reflections and diffractions. This migration technique generally requires *a priori* knowledge of the strike direction of crustal reflectors, but where correlatable intersecting profiles are available it is possible to solve for reflector strike. We illustrate our method using synthetic data sets and real data examples from Lithoprobe profiles for which the reflector strike is well-constrained.

Introduction

In conventional processing of seismic lines, the initial results are stack profiles in which reflections with varying amplitudes and shapes with the exception of continuous flat-lying reflections do not represent the true sub-surface geometry and locations of the reflectors. This is especially true for deep-crustal profiles, where dipping reflections noted in the lower crust and upper mantle in stack profiles may originate many kilometers from their true subsurface positions. So, seismic migration which places the reflectors at their true sub-surface locations and reveals the true geometry is required for correct interpretation. Many 2-D migration schemes in the time and frequency domains are routinely used for this purpose. They assume that all of the reflections observed in the stack profiles are in-plane reflections. In reality, the geometry of the sub-surface is 3-D, and hence, reflections observed in 2-D profiles originate from 3-D structure, and therefore, are a mixture of in-plane and out-of-plane reflections. Hence, any interpretation of 2-D processed results could be misleading and erroneous (Cohen & Bleistein, 1983).

Drummond et al. (2004) and Hobbs et al. (2006) have recently investigated the influence of the 3D geometry of the sub-surface in 2D crustal reflection profiles. For instance, the presence of out-of-plane topography on reflectors leads to reflections with inaccurate reflector shapes. Also, reflectors that are a single surface may appear as a band of several reflections. Most importantly, out-of-plane reflections migrate to an apparent depth greater than the in-plane reflections do. These observations suggest that the in-plane structure which results from in-plane migration may not truly reflect the out-of-plane structure.

Many land-based 2D deep-crustal seismic lines acquired under the LITHOPROBE project in the past two decades have crooked line geometry. This affords an opportunity to do 3-D migration if the fold of the 3-D geometry resulting from the crooked line is appreciable. In some instances, there are intersecting seismic lines where 3-D structures play out differently in each one of the 2D stack profiles. In all of these, intrinsic to the reflection geometry are the two-way travel times. In recent years, seismic skeletonization (Vasudevan et al. 2005) has been used as a tool to extract the two-way travel times. Alternatively, digitization methods can be applied to electronic versions of the paper copies of the stacks. With these options available to use, we propose here a simple ray-based skeleton-migration method to gain an insight into 3-D structures from 2-D results. We assume a constant velocity for the medium to keep the problem tractable. We illustrate the method with the skeletonized results of real data.

Method

Skeleton-migration introduced here has two steps. In the first step, seismic skeletonization of the data being investigated is carried out. This yields a digital catalogue of two-way travel times from the 2-D stack reflection profiles. In the second step, ray-based migration is applied. Straight ray-based migration has been discussed in literature (Raynaud, 1988; Eaton & Hynes, 1999, 2000; Li & Eaton, 2005) and used to glean an understanding of the in-plane and out-of-plane reflections. Essential to the ray-based migration is the availability of two-way travel times of the

2-D stack profiles and an *a priori* knowledge of the dip direction and velocity of the reflecting layer. For many deep-crustal reflection profiles, constant-velocity migrations are routinely carried out. This lends itself nicely to easy ray-based migration.

Examples

We show in Figure 1 the study area. The seismic line we use here for an illustration of the method is SALT(Southern Alberta Lithosphere Transect) 29, and the details relevant to the SALT lines may be found in http://www.litho.ucalgary.ca/atlas/abt/abt_menu.html). Figure 2 is a cartoon display of the unit vectors used for out-of-plane migration of the reflection segments in the stack section. We apply the out-of-plane skeleton-migration method to the stack profile. We consider only the bottom 9 s (TWT) of the data for migration. In Figure 3, we show the skeletonized result of the stack profile and three examples of in-plane projected results of out-of-plane migration on the stack profile.

Conclusions

We present an easy-to-implement skeleton-migration algorithm. Using both synthetic and real data examples, we demonstrate that we could gain a better understanding of the influence of the 3-D geometry of reflecting surfaces in conventionally-processed 2-D reflection profiles.

Acknowledgements

The authors would like to thank the Natural Sciences and Engineering Research Council of Canada for financial support. We acknowledge the use of the SALT data acquired under the LITHOPROBE programme in 1995.

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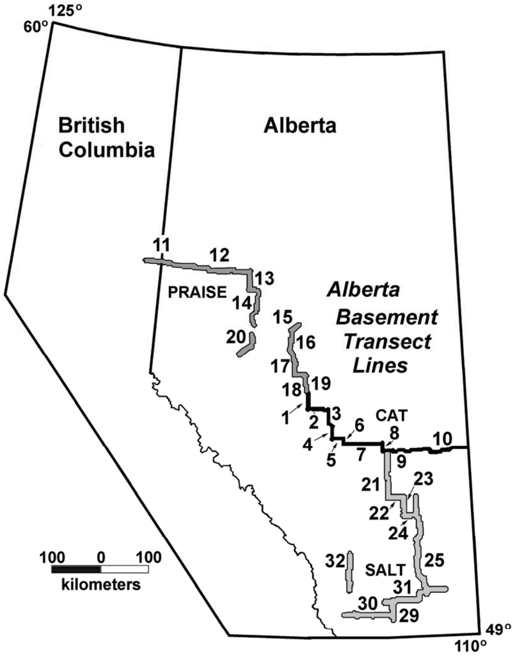

Figure 1. Location map of the study area

(Adapted from the Lithoprobe Atlas)

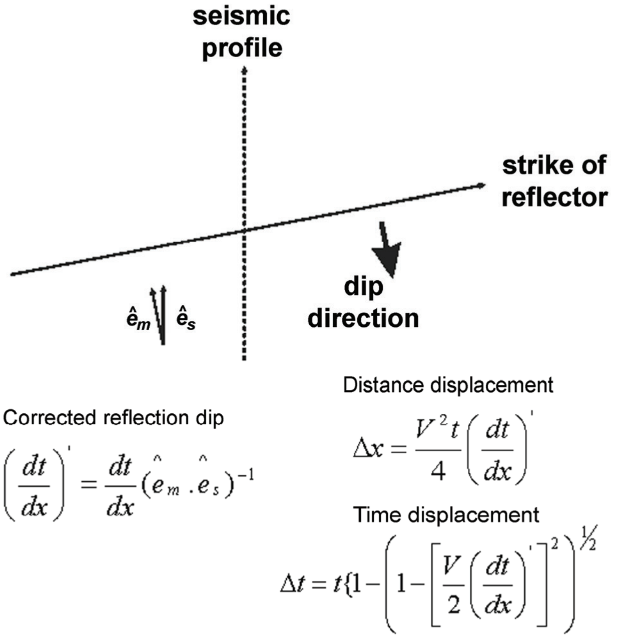

Figure 2. Unit vectors for out-of-plane migration of skeletonized events

(Adapted from Li&Eaton, 2005)

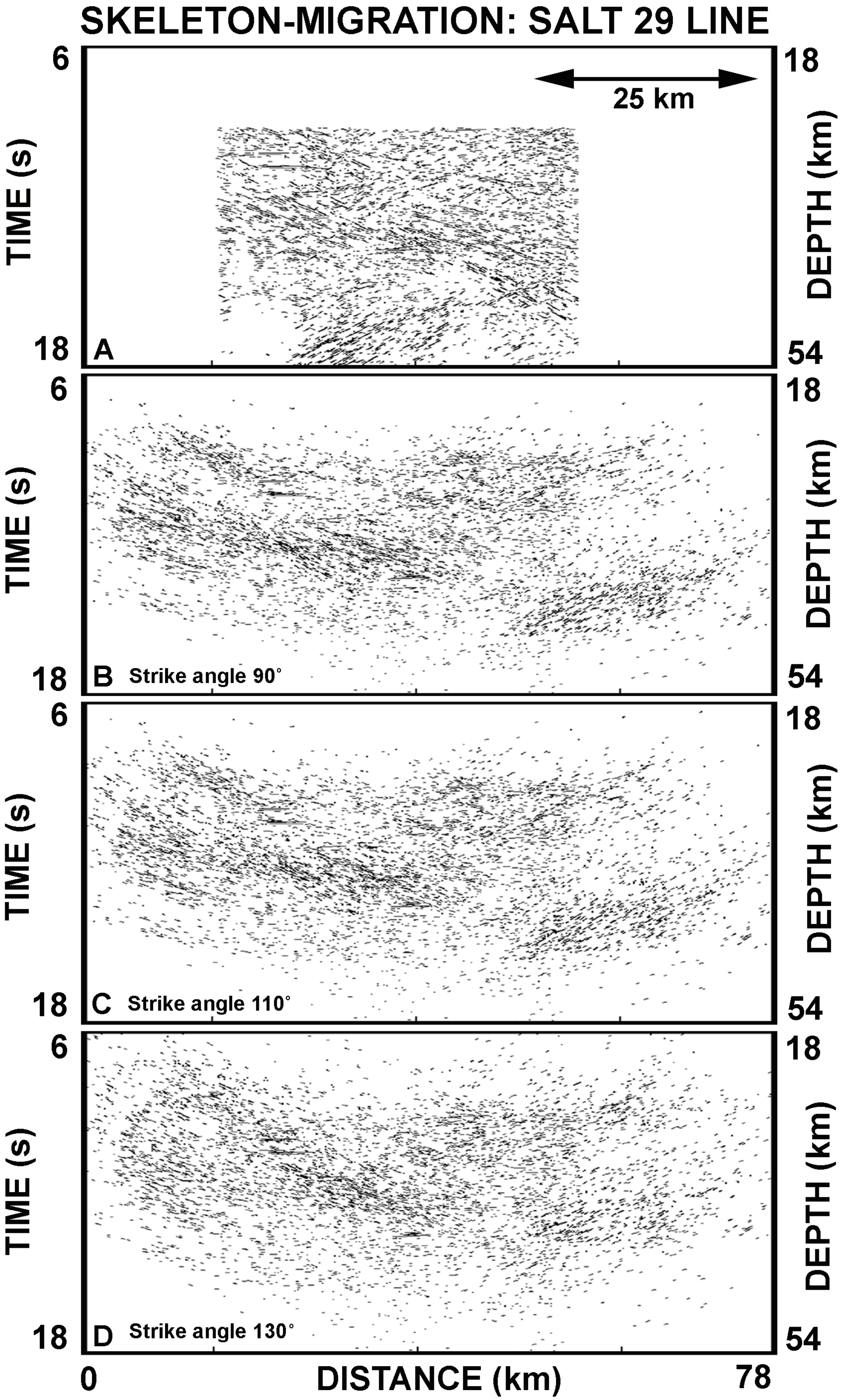

Figure 3. Skeleton (A) and in-plane projected results (B, C, D)